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75-79 CEMEL

VERIFICATION FIT TEST OF THREE SIZE INFANTRY HELMET

by
Lawrence R. McManus
William D. Claus
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and
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January 1975

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NATICK, MASSACHUSETTS 01760

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This report presents the statistical analysis of data generated by a fitting test of a 3 size infantry helmet system. The report includes analyses of anthropometric head data over the total population of 403 test subjects as well as an analysis of the population within each size for the three helmets. In addition, the report presents an analysis of helmet stand-off from the head as compared to a designed minimum stand-off of 12.5mm.

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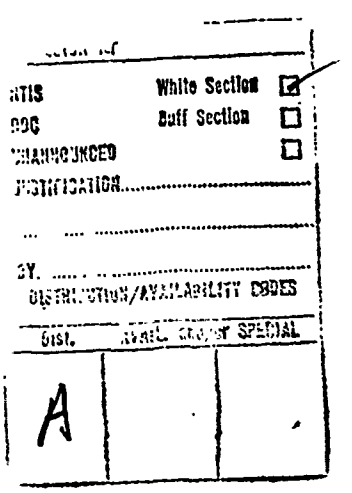

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1. Introduction

The object of this report is to present the statistical analysis of a fitting test of a three size helmet system. The test was conducted at Ft. Devens, MA during six days in July 1974 using men from the 10th Special Forces as test subjects.

Although it is not the intent of the authors to detail here the steps involved in the development and design of the new infantry helmet, it is essential that the reader have an appreciation, at least in capsule form, for the systematic approach in the design of the helmet.

Under the US Army Materiel Command Five-Year Personnel Armor System Program, several work unit reports are available which are pertinent to the design of the infantry helmet. Natick Development Center (NDC) Technical Report 75-23-CEMEL, entitled "Development of Headforms for Sizing Infantry Helmets", details the necessity for and the development of new shaped headforms representing the US Army population. NDC Technical Report 74-29-CE, "Heat Transfer Properties of Military Protective Headgear", and the Edgewood Arsenal Draft report, "Transient Deformation of Military Helmet and Its Injury Potential", establish the optimum helmet stand-off from the head for ventilation and transient deformation protection. Both reports establish this stand-off to be 12.7mm.

With this information documented, NDC personnel fabricated hydrocal "working helmet molds" in three sizes. This was accomplished by adding 12.7mm normal to the surface of the headforms. Human Engineering Laboratories (HEL), APG, MD conducted studies under the program work unit HLR-7 to establish the edge cut criteria for the helmet; i.e. the lower periphery of the helmet that would maximize head coverage consistent with the infantryman's task. These studies included: vision; audition; employment of shoulder-fired weapons; fire control systems; optics for other aimed, non-weapon systems; and binocular/monocular vision enhancement devices; compatibility with clothing ensembles and also body-borne equipment and worn protective systems. The edge-cut criteria are included in the work units program report dated November 74, entitled "Summary of Infantry Helmet Edge-Cut Criteria".

These edge-cut criteria were inscribed on the "working helmet molds" giving the developer a line of demarkation above which a designed helmet would have optimum compatibility and below which a designed helmet would interfere with or be incompatible with some aspects of the infantry man's operation or mission.

Having established the essential design criteria for a helmet, namely size, stand-off and edge-cut, NDC personnel, together with sculptor and artist Mr. A. Petitto, designed numerous helmets over the "working helmet mold".

One design was selected and hydrocal molds were made in three sizes suitable for vacuum forming. Plastic (ABS) helmet prototypes were fabricated at NDC having the simulated thickness and weight to meet the Materiel Need document. (Fig-1) Suspension systems were inserted in the helmets, and the helmets were shipped to HEL in April 74 for human factors evaluation in the field. It was this same design that was used in the fitting test at Ft. Devens, MA.

2. Method

Subjects: 403 Officers and enlisted men of the 105h Special Forces Stationed at Ft. Devens, MA served as subjects.

Procedure:

The subjects were given a record sheet on which they filled in their name, rank and social security number. (Fig-2) The anthropometric measurements taken and recorded for each subject's head included circumference, length, breadth, height, glabella to vertex, biaural breadth (ear to ear) and menton to vertex. Menton to vertex measurements were included to extend the base of such data for future use in development of face shields etc. (See figures 3 to 9)

The subject was given a helmet size designation according to the following sizing criteria.

Dimension	Small (mm)	Medium (mm)	Large (mm)
Circumference	555	576	611
Length	193	200	210
Breadth	151	159	166

Instruction: A subject whose measurement is plus in any dimension is placed in the next higher size.

The subject was then fitted with a clear polycarbonate helmet shell w/suspension system of the designated size. Each shell had 13 numbered probe holes as depicted in Fig-10. The stand-off was checked by probing the distance of the shell from the head. All probe readings less than 12.7mm were recorded on the subject's record sheet.

3. Discussion

Table I shows the statistics for the entire population of 403 men and the tariff of sizes. The tariff of approximately 20, 50, 30 percent, respectively for small, medium and large is an excellent distribution of helmet sizes.

Table II thru XXV depict the within-size statistics and individual dimension distribution. It is observed that each of the Tables showing the distribution of dimensions used in the sizing criteria, namely circumference, length and breadth, have a small number of subjects over the respective dimensional limit for that particular size. Thus, according to the sizing instructions, these subjects would normally be placed in the next higher size. However, these particular individuals were border line cases in that their other dimensions were considerably smaller than the respective maximum limits. A judgement was made by the measurer or a preference was made by the subject to designate the smaller size.

It should be pointed out that the glabella to vertex (GV) measurement, Tables VII, XV, and XXIII is the most relevant height measurement to a helmet designer. The GV tables show that the range and distribution of measurements are similar for all three sizes encompassing the 5th to 95th percentile. In other words, the glabella to vertex dimension is independent of head size, a most important consideration to the helmet designer. This result is consistent with other studies (for example, NDC Technical Report 72-52-CE, "Anthropometry of US Army Aviators - 1970") where it is shown that the GV dimension is virtually uncorrelated with other major head dimensions. This data confirms the decision made early in the program by the helmet designers, to modify the three helmet molds by increasing the GV dimension to correspond to the 75th percentile of the Army population. The stand-off of the helmet from the head is as important as the distribution of sizes. The helmet system was designed to stand-off a minimum of 12.7mm from the 1st to 99th percentile head of the Army population. Table XXVI presents the stand-off data in terms of number of probe readings less than 12.7mm. An analysis and explanation of the data reveal the following:

a. Probe station #1, stand-off at the vertex, recorded a total of 43 sub readings due to approximating the 12.7mm stand-off on the first day. A 12.7mm thick, small "stop" placed in the crown of the shell insured minimum stand-off in this area thereafter.

b. The remainder of the 5% of the total probe readings, under 12.7mm, were clustered about the length and width probes. The average of these probe readings under 12.7mm were below the designed value by approximately 2.5mm; the inferior value thus averaged about 10.2mm, but even this small difference could be accounted for if the shrinkage of the polycarbonate plastic was taken into consideration. However, since the ballistic materials under consideration for the helmet have some degree of shrinkage after molding (but less than the polycarbonate) these probe readings were used to "fine tune" the molds with respect to the length and width dimensions.

4. Conclusions

1. The three size infantry helmet system fits the US Army population exhibiting a tariff of approximately 20, 50, 30 percent for the respective sizes of small, medium and large.

2. The helmet system in three sizes, after a very slight modification to length and width, will have a 12.7mm minimum stand-off at all points on the head.

FIG 1

INFANTRY HELMET FIT TEST

NAME:

Subject Number: [ ][ ][ ] (1 2 3)

S.S. NO.:

UNIT:

Head Dimensions

Circumference [ ][ ][ ] (4 5 6)

Length [ ][ ][ ] (7 8 9)

Breadth [ ][ ][ ] (10 11 12)

Height [ ][ ][ ] (13 14 15)

Glabella-Vertex [ ][ ] (16 17)

Ear-Ear [ ][ ][ ] (18 19 20)

Menton-Vertex [ ][ ][ ] (21 22 23)

Sizing System (Head Dimensions)

			Subject's Helmet Size
Large	611	210	166
Medium	576	200	159
Small	555	193	151

Helmet Offset Measurements

Probe No. Offset (in.)

1. _____ 5. _____ 9. _____

2. _____ 6. _____ 10. _____

3. _____ 7. _____ 11. _____

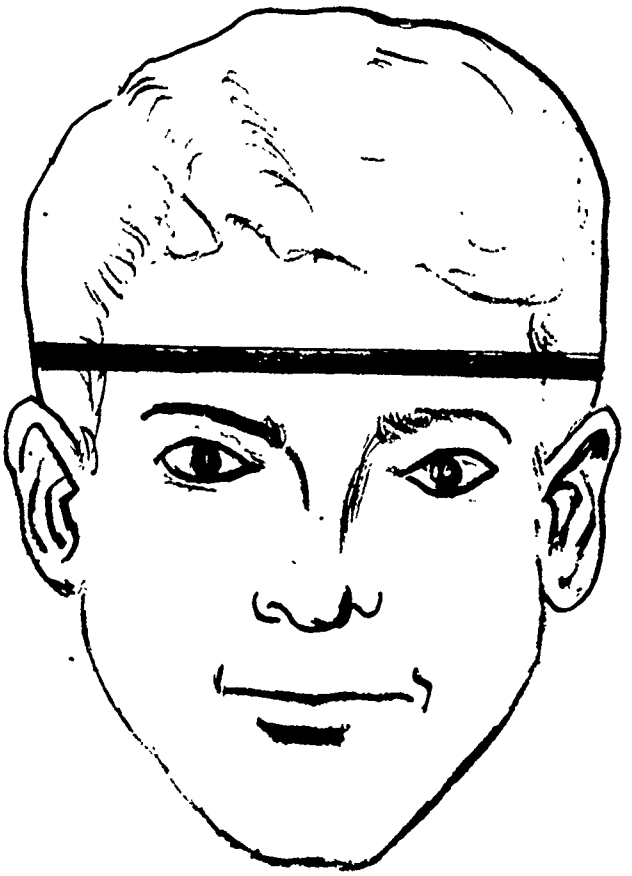
4. _____ 8. _____ 12. _____

13. _____

Remarks.

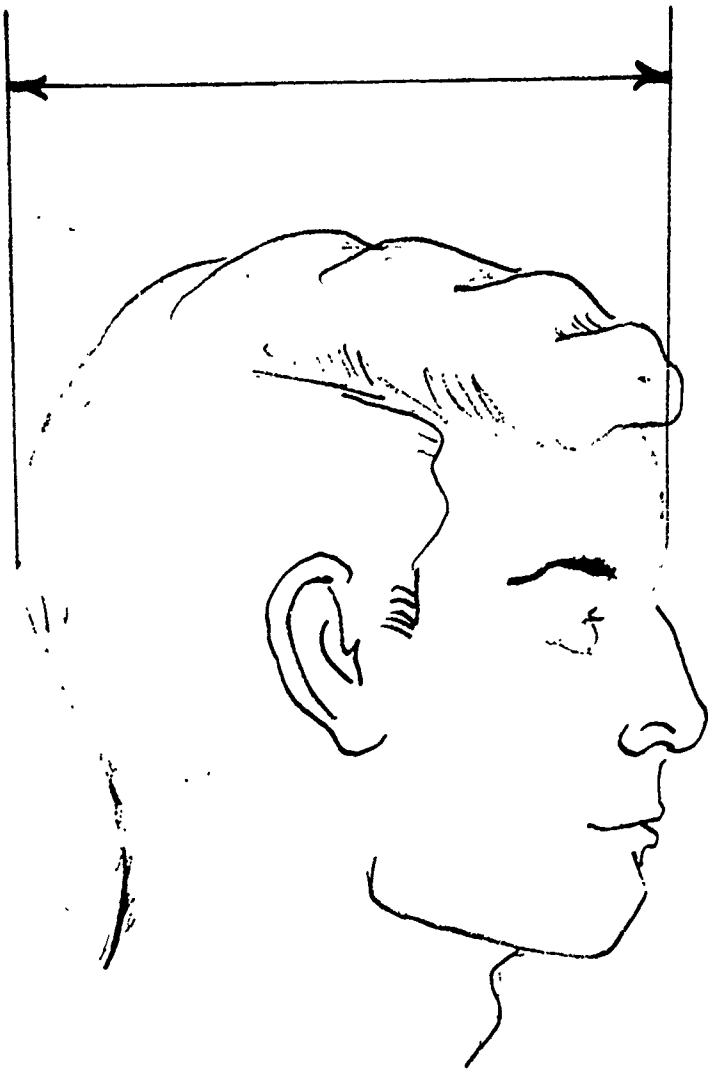
Fig-2

Fig-3



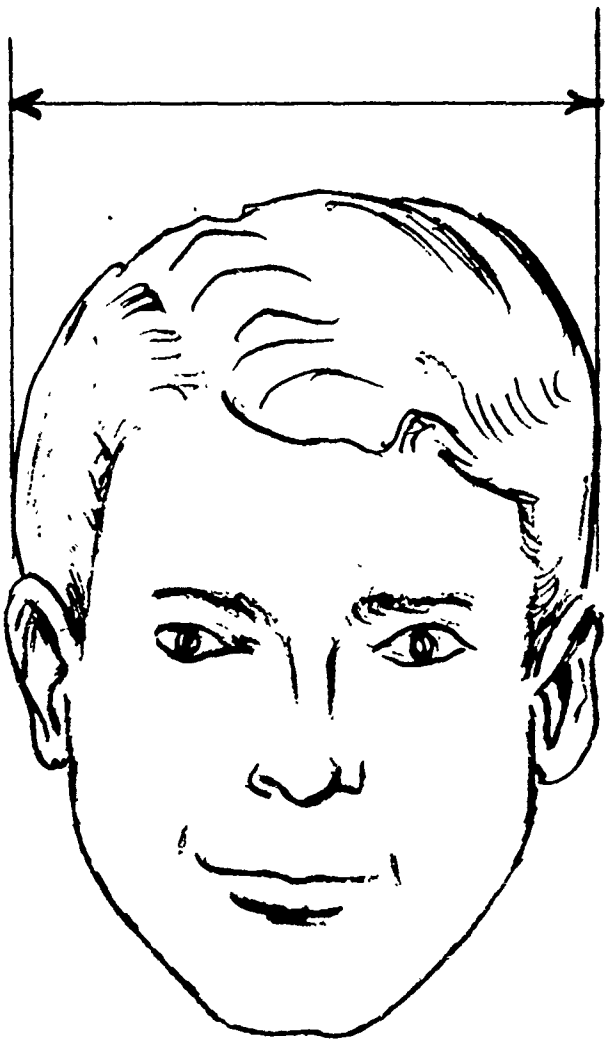
Head Circumference: Subject sits erect with head level. The maximum circumference of the head is measured. A steel tape is used, with the tape passing just above the bony brow ridges of the forehead and above both ears.

Fig-4



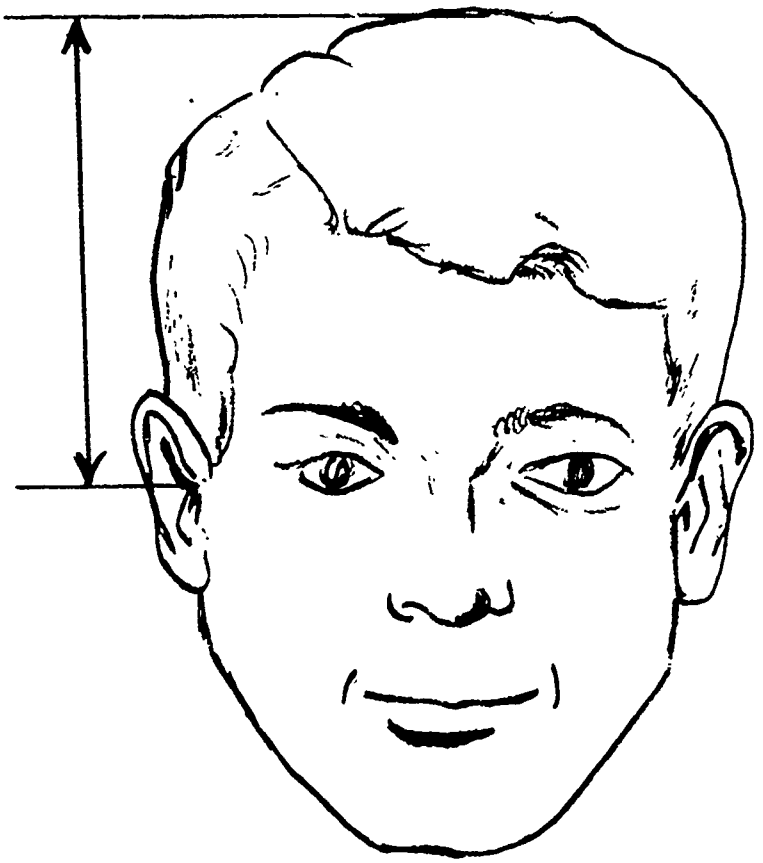
Head Length: Subject sits erect with head level. The maximum length of the head is measured from the back of the head (occiput) to the forehead (glabella) spreading calipers are used.

Fig-5



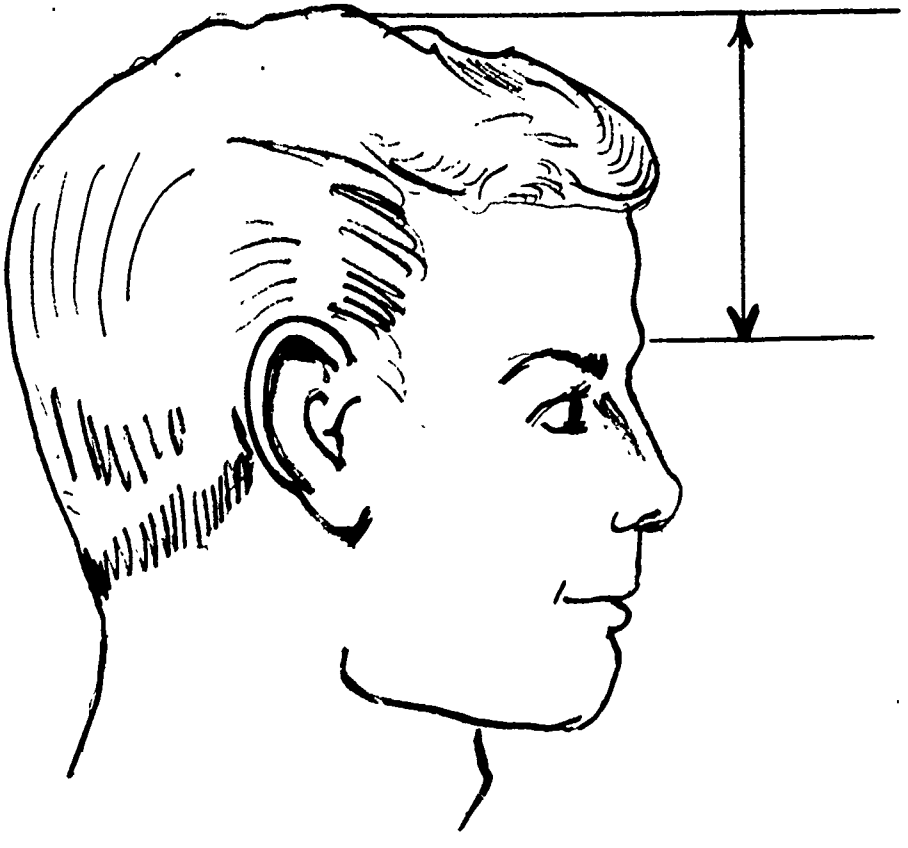
Head Breadth: Subject sits erect with head level. The maximum horizontal breadth of the head is measured above and behind the ears. Spreading calipers are used.

Fig-6



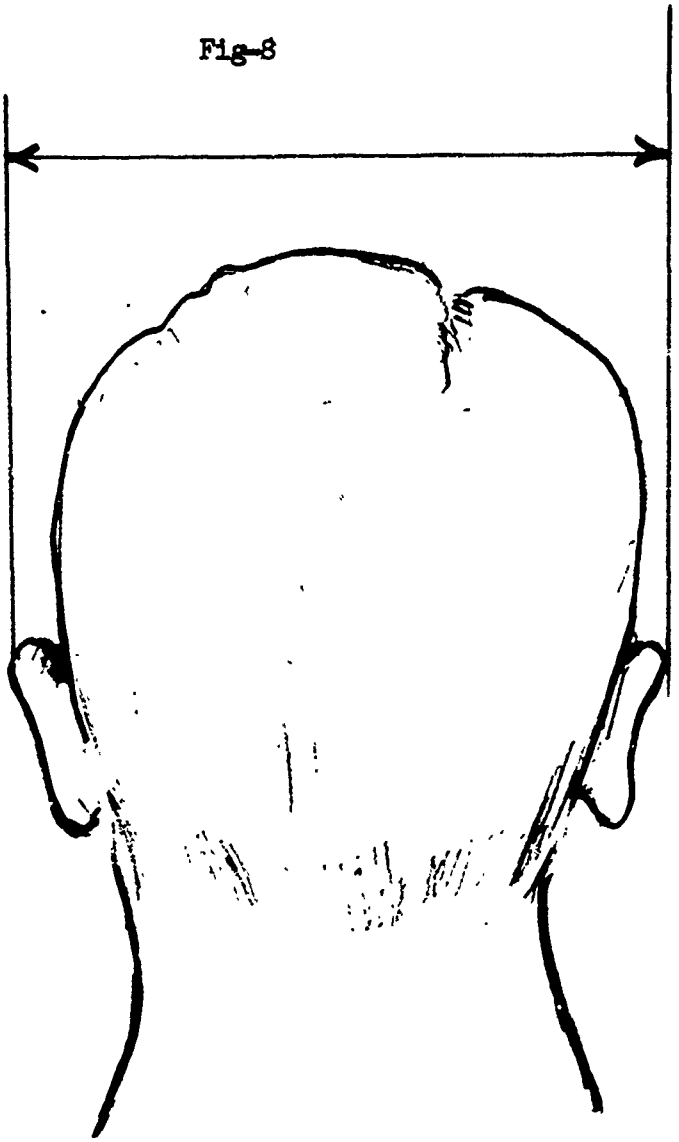
Head Height (Tragion - Vertex Height): Subject sits erect, with head level. Head height is measured as the vertical distance from the cartilaginous notch (tragion) at the front of the right ear to the top of the head (vertex). An anthropometer is used.

Fig-7



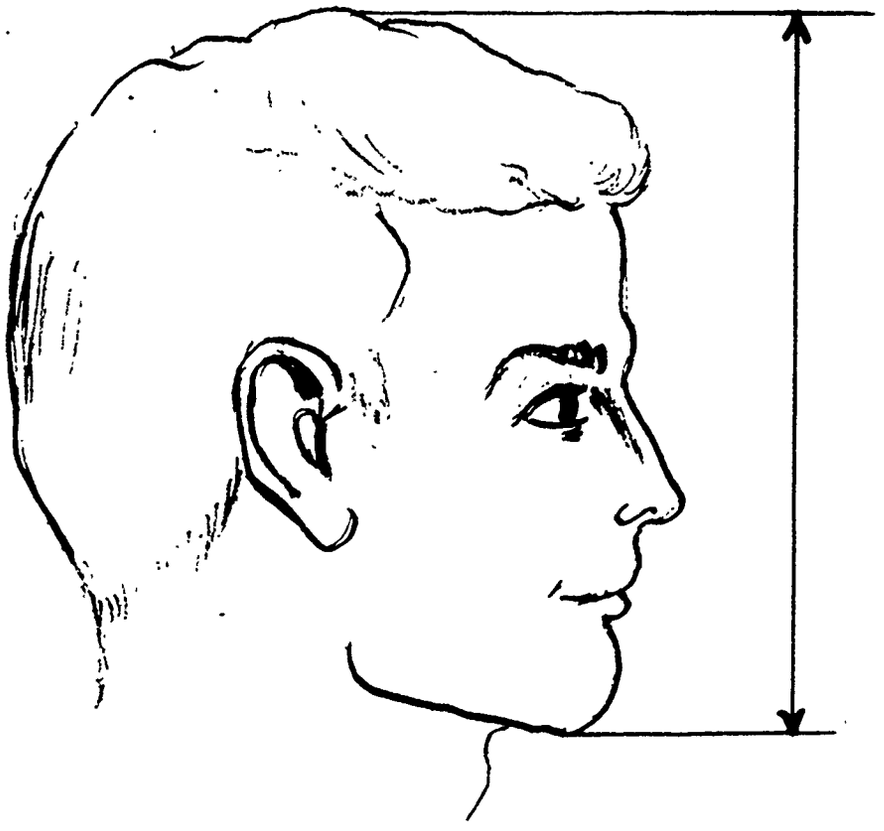
Glabella to Vertex: Subject sits erect, with head level. The maximum vertical distance from the glabella land mark to the top of the head (vertex) is measured.

Fig-8



Biaural Breadth: Subject sits erect, with head level. The maximum horizontal distance from the outside of one ear to the outside of the other ear is measured. Spreading calipers are used.

Fig-9



Menton to Vertex: Subject sits erect, with head level. The vertical distance from the bottom of the chin (menton) to the top of the head (vertex) is measured. An anthropometer is used.

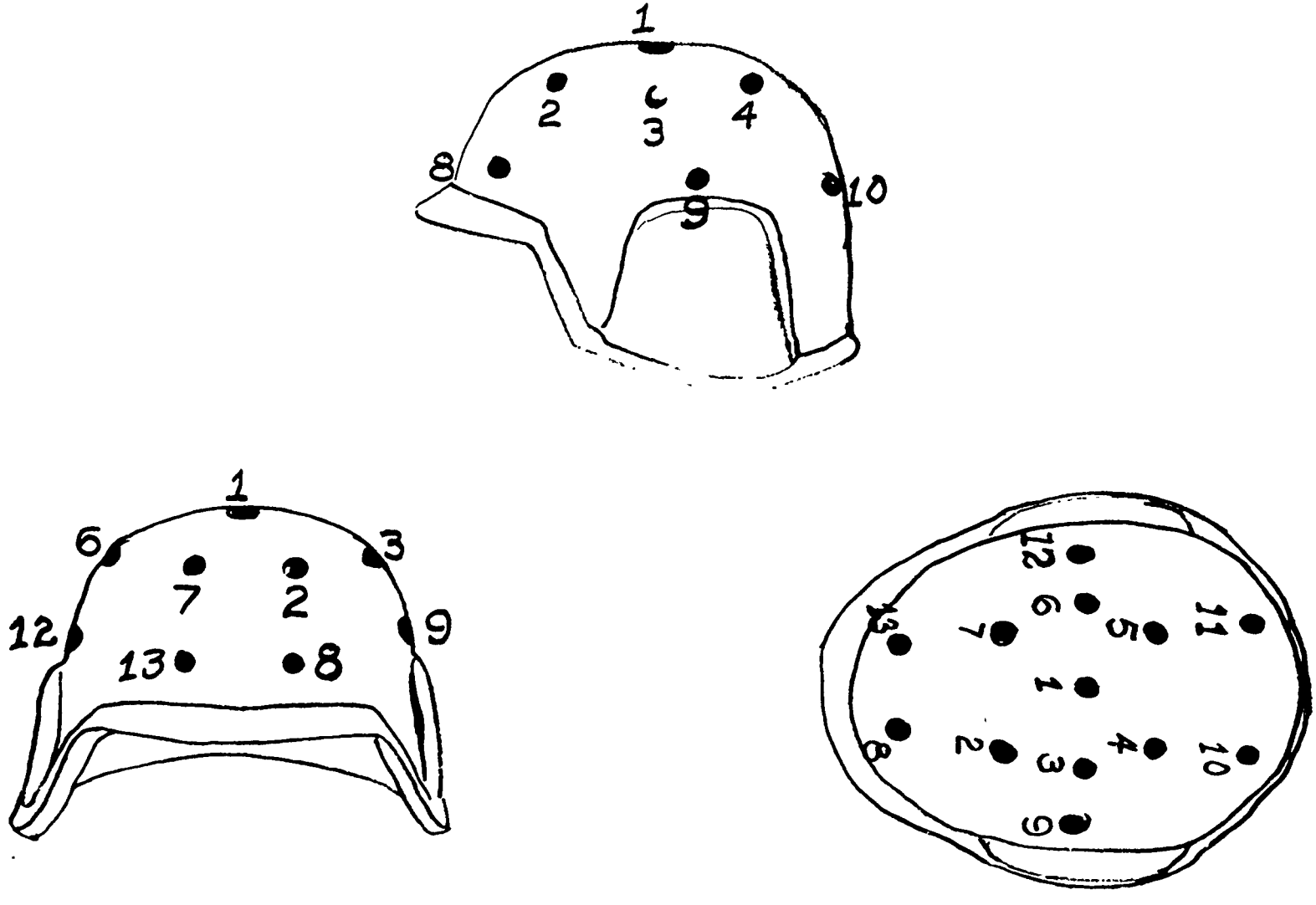


Fig 8-10 Helmet Stand-Off Probe Stations

TABLE I

Analysis of Head Dimensions of a Military Population

Population - 403 Men
Population Consists of:

82 Size Small - - - 20.35%
198 Size Medium - - 49.13%
123 Size Large - - - 30.52%

DIMENSION	MEAN (mm)	STD DEV	MINIMUM (mm)	MAXIMUM (mm)
Circumference	567.66	15.12	520.00	619.00
Length	193.87	7.09	171.00	215.00
Breadth	152.18	6.18	134.00	170.00
Height	128.20	6.14	110.00	146.00
Glabella-Vertex	84.68	9.34	57.00	113.00
Ear to Ear	186.95	8.74	159.00	208.00
Menton-Vertex	221.51	10.27	194.00	288.00

TABLE II

Analysis of Head Dimensions of a Military Population
Sized Small

Population - - - 82 Men

DIMENSION	MEAN (mm)	STD DEV	MINIMUM (mm)	MAXIMUM (mm)
Circumference	547.71	7.20	520.00	560.00
Length	186.93	4.66	175.00	196.00
Breadth	146.91	4.57	134.00	155.00
Height	124.59	5.09	114.00	137.00
Glabella-Vertex	83.12	9.44	66.00	105.00
Ear to Ear	181.91	7.50	159.00	199.00
Menton-Vertex	215.72	8.89	196.00	237.00

TABLE III

Frequency Distribution of Size Small Head Circumference

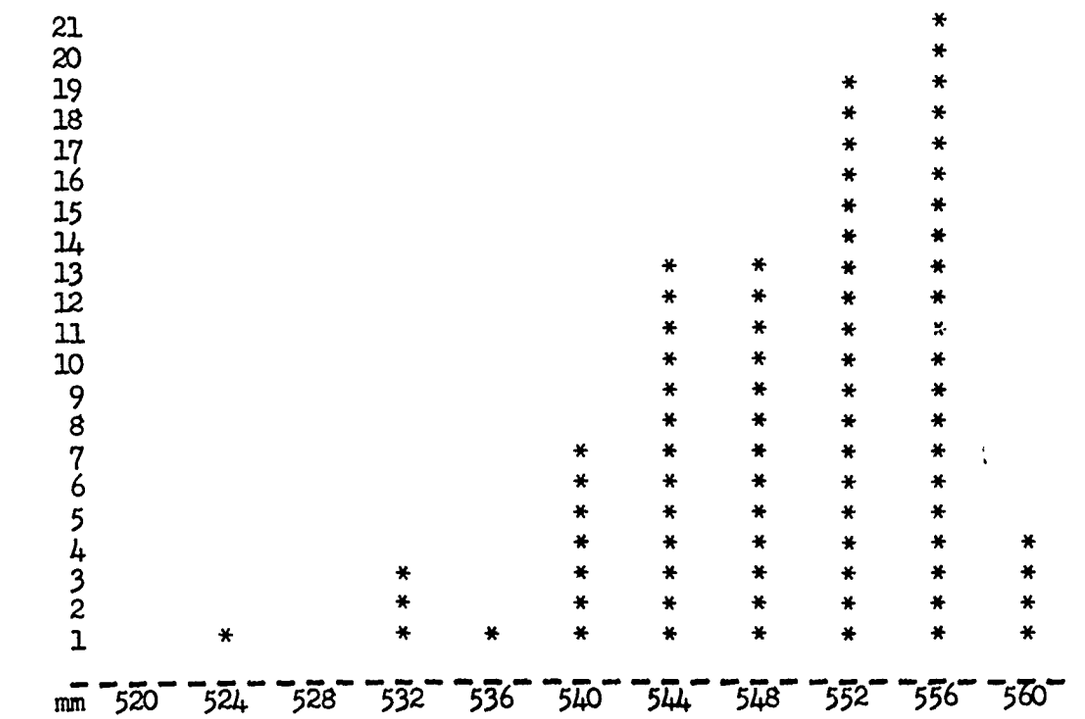


TABLE IV

Frequency Distribution of Size Small Head Length

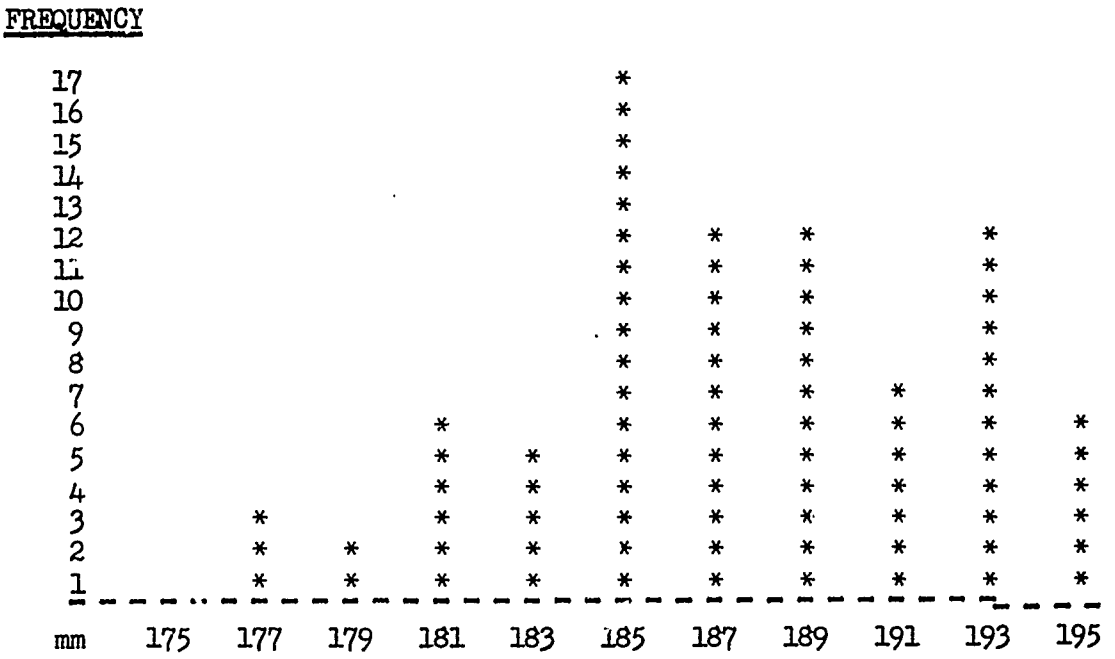


TABLE V

Frequency Distibution of Size Small Head Breadth

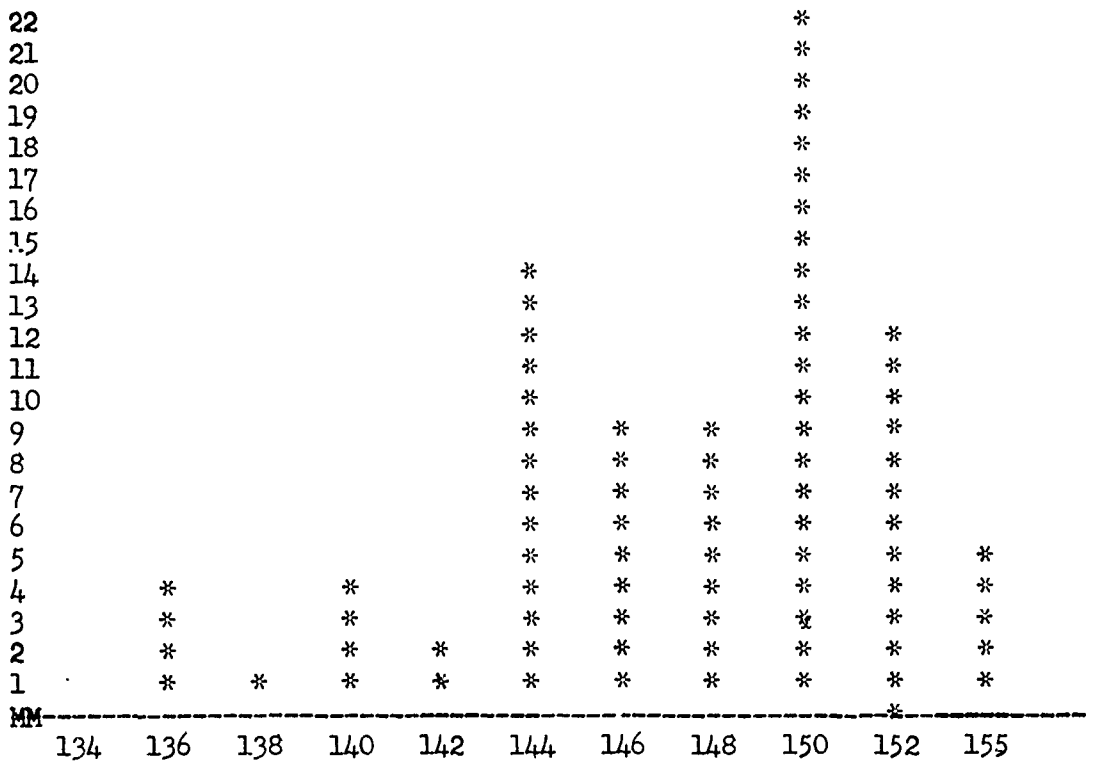


TABLE VI

Frequency Distribution of Size Small Head Height

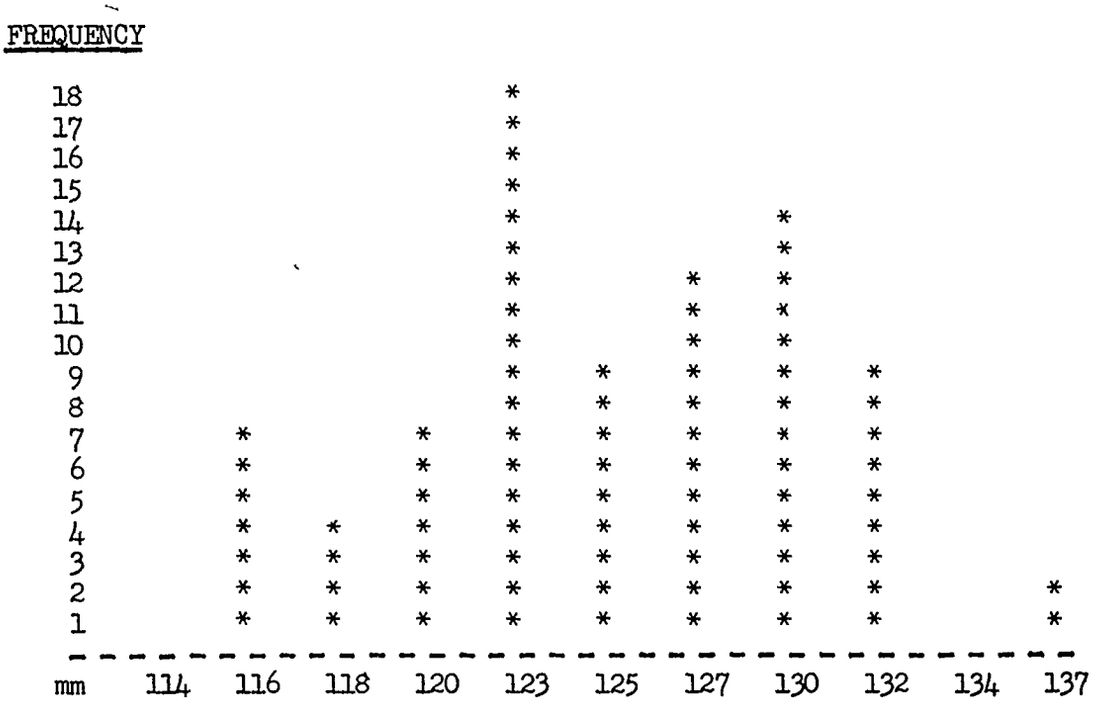


TABLE VII

Frequency Distribution of Size Small Glabella to Vertex

Frequency											
15				*							
14				*							
13				*		*					
12			*	*		*					
11			*	*		*					
10			*	*	*	*	*				
9			*	*	*	*	*	*			
8			*	*	*	*	*	*			
7			*	*	*	*	*	*			
6			*	*	*	*	*	*			*
5			*	*	*	*	*	*			*
4			*	*	*	*	*	*	*		*
3			*	*	*	*	*	*	*		*
2		*	*	*	*	*	*	*	*		*
1		*	*	*	*	*	*	*	*	*	*
MM	65	69	73	77	81	85	89	93	97	101	105

TABLE VIII

Frequency Distribution of Size Small Biaural Breadth

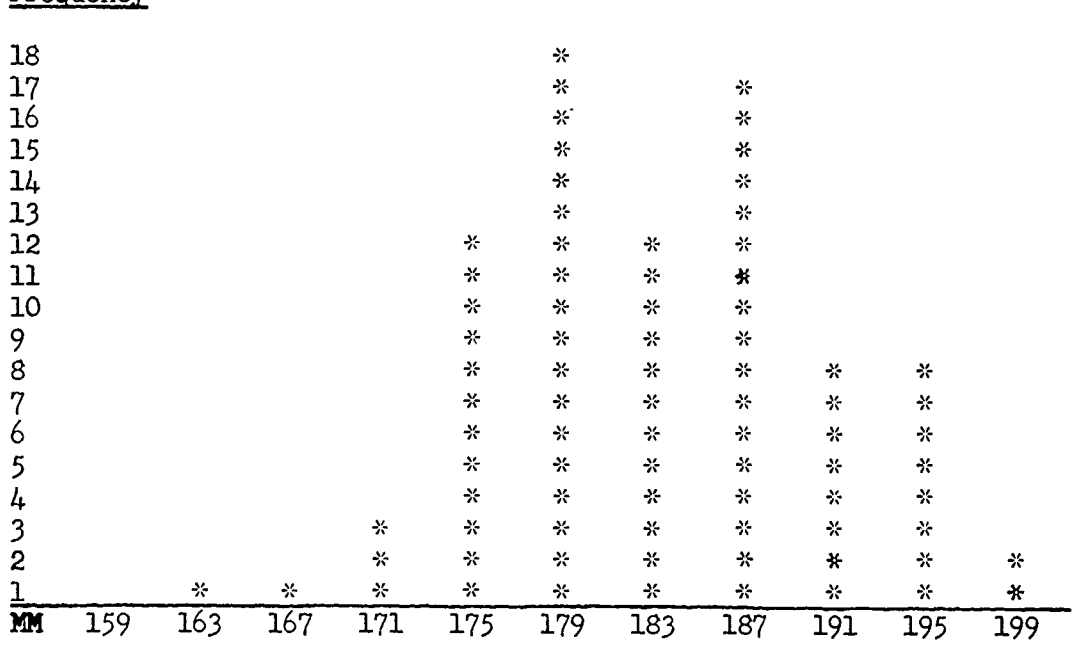


TABLE IX

Frequency Distribution of Size Small Menton to Vertex

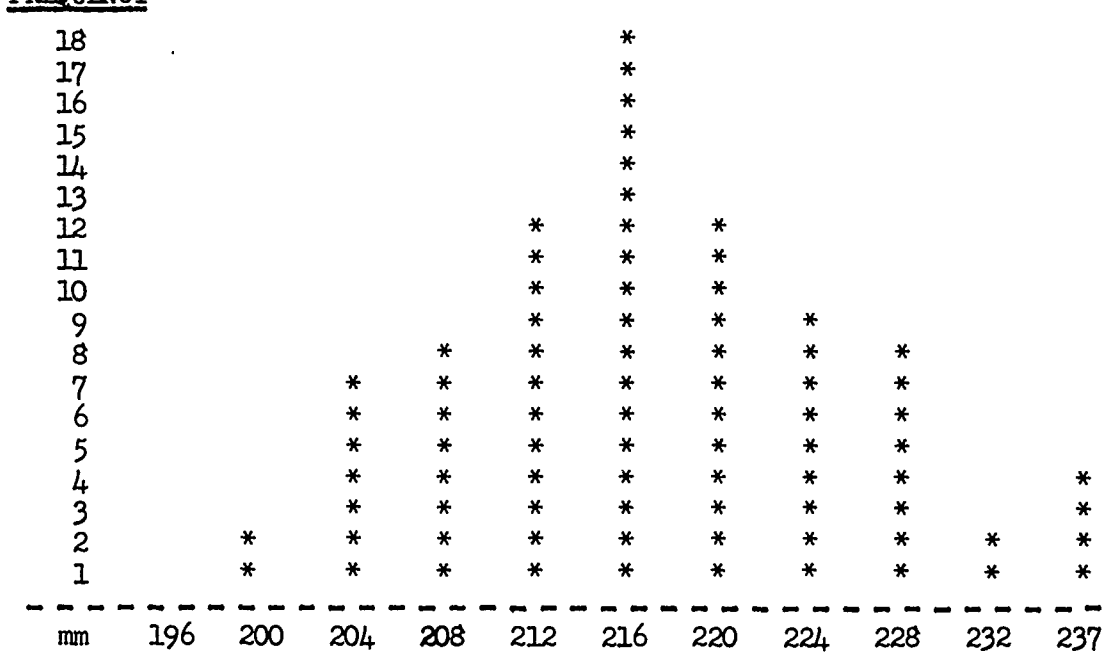


TABLE X

Analysis of Head Dimensions of a Military Population Size Medium Population -- 198 Men

Dimension	Mean(MM)	STD DEU	Minimum(MM)	Maximum(MM)
Circumference	565.59	7.28	543.00	590.00
Length	193.07	5.36	171.00	204.00
Breadth	151.74	5.12	134.00	165.00
Height	127.76	5.76	110.00	146.00
Glabella-Vertex	84.27	9.32	57.00	110.00
Ear to Ear	186.59	7.96	160.00	208.00
Menton-Vertex	221.48	9.69	194.00	288.00

TABLE XI

Frequency Distribution of Size Medium Head Circumference

Frequency											
27						*					
26						*					
25						*					
24						*			*	*	
23						*			*	*	
22						*			*	*	
21						*			*	*	
20						*	*		*	*	
19						*	*		*	*	
18						*	*		*	*	
17						*	*		*	*	
16						*	*		*	*	
15						*	*		*	*	
14						*	*		*	*	
13						*	*		*	*	
12						*	*		*	*	
11						*	*	*	*	*	
10					*	*	*	*	*	*	
9					*	*	*	*	*	*	
8					*	*	*	*	*	*	
7					*	*	*	*	*	*	
6					*	*	*	*	*	*	
5					*	*	*	*	*	*	
4			*		*	*	*	*	*	*	
3			*		*	*	*	*	*	*	*
2			*		*	*	*	*	*	*	*
1		*	*	*	*	*	*	*	*	*	*
MM	543	546	550	554	557	561	564	568	571	575	580

TABLE XII

Frequency Distribution of Size Medium Head Length

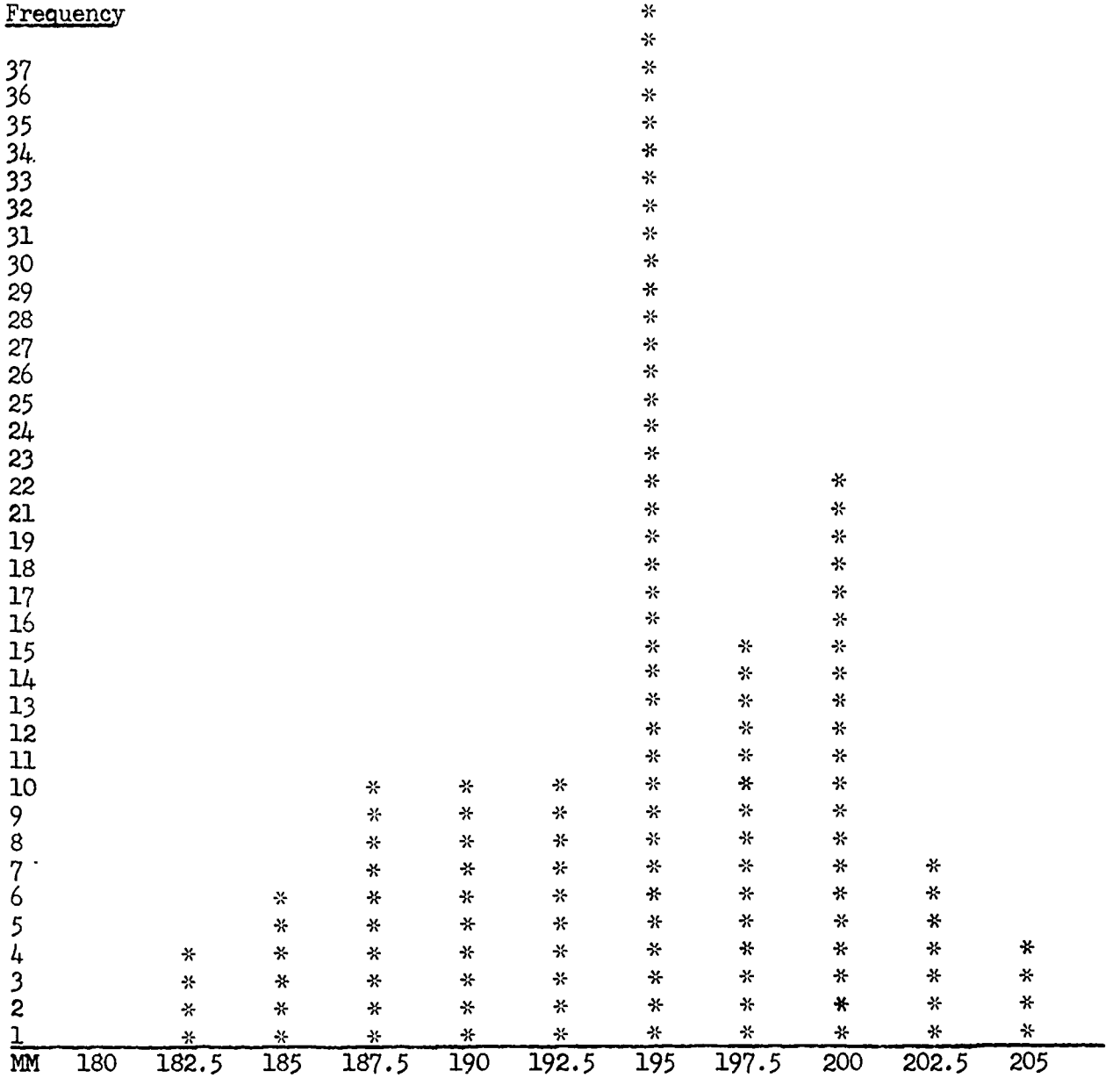


TABLE XIII

Frequency Distribution of Size Medium Head Breadth

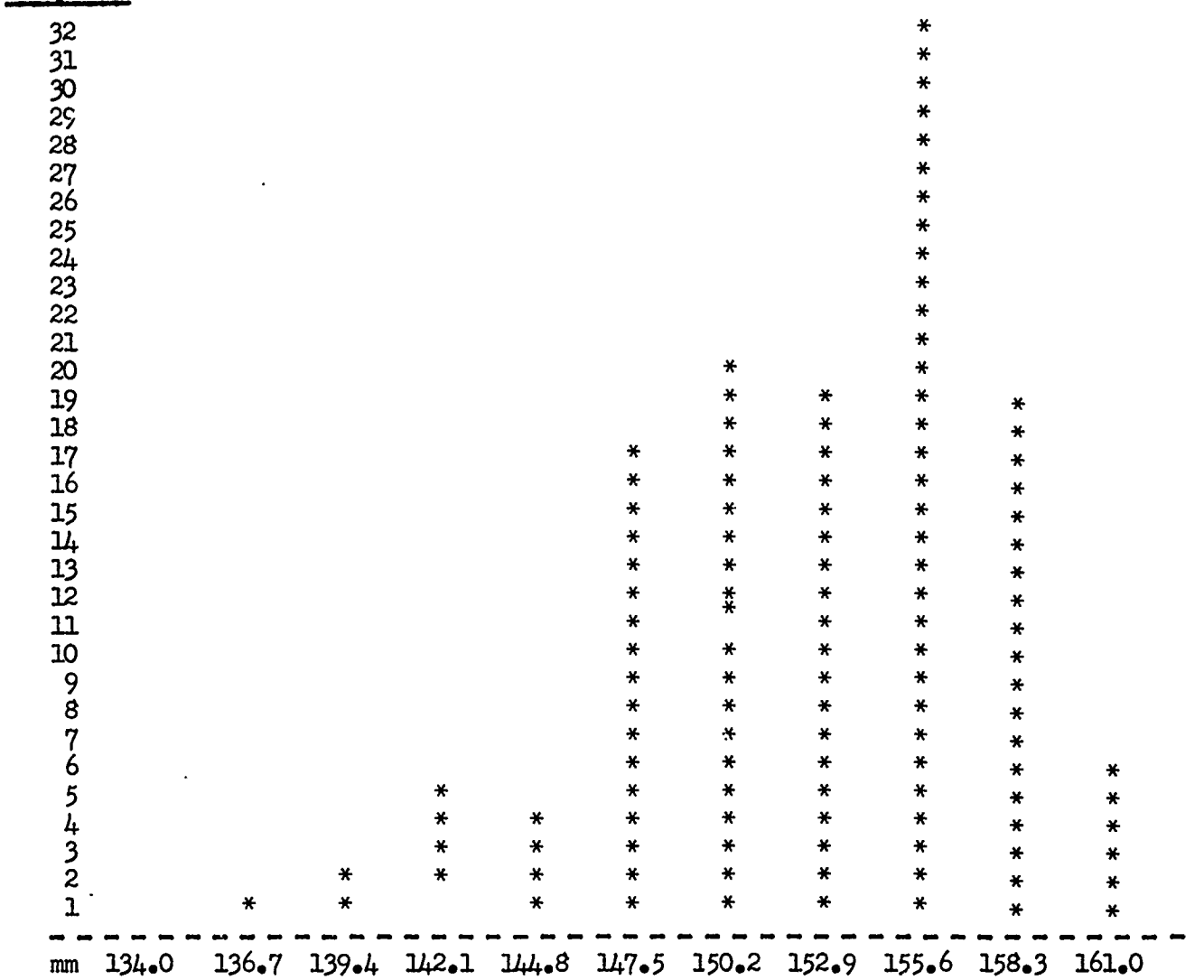


TABLE XIV

Frequency Distribution of Size Medium Head Height

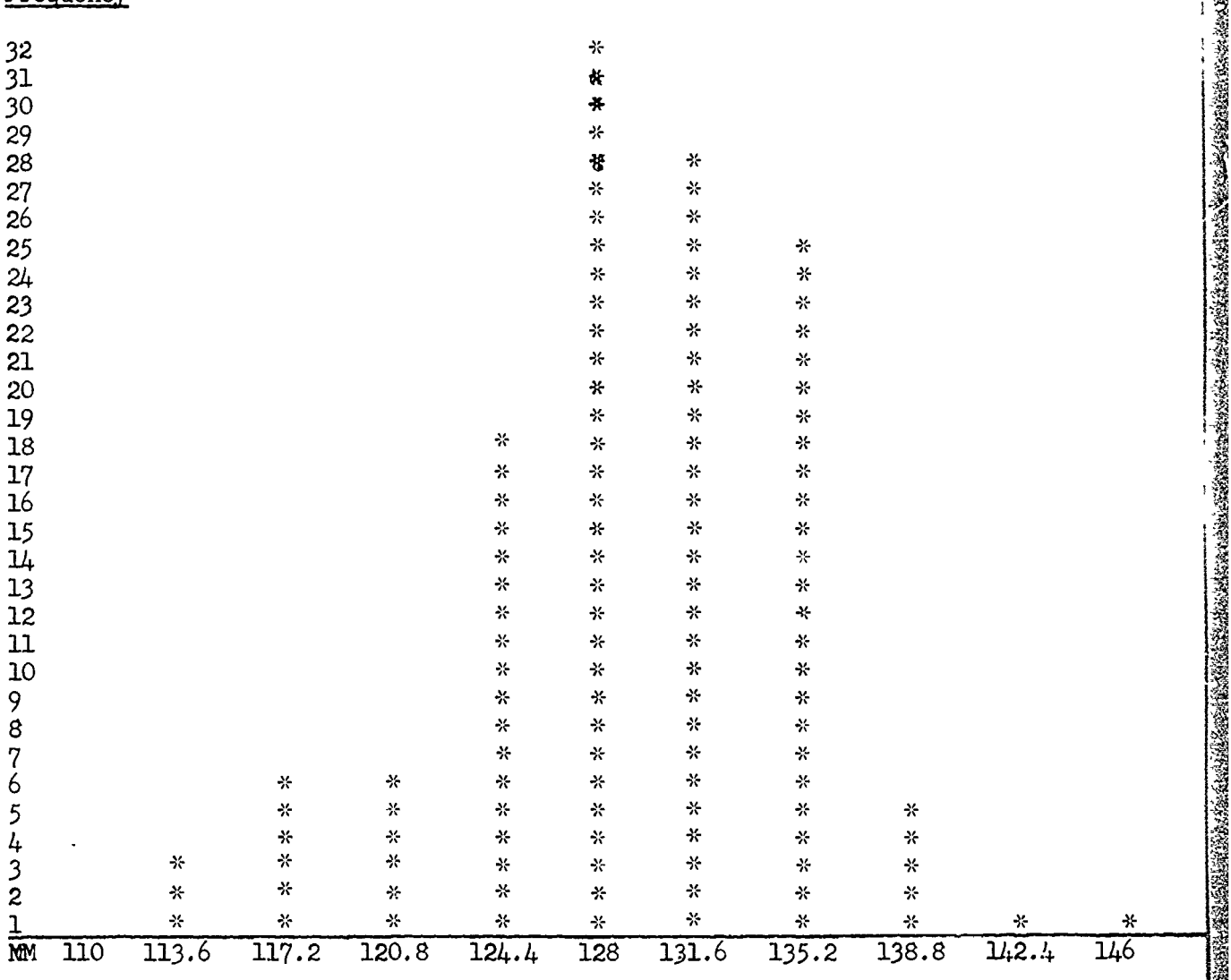


TABLE XV

Frequency of Distribution of Size Medium Glabella to Vertex

Frequency

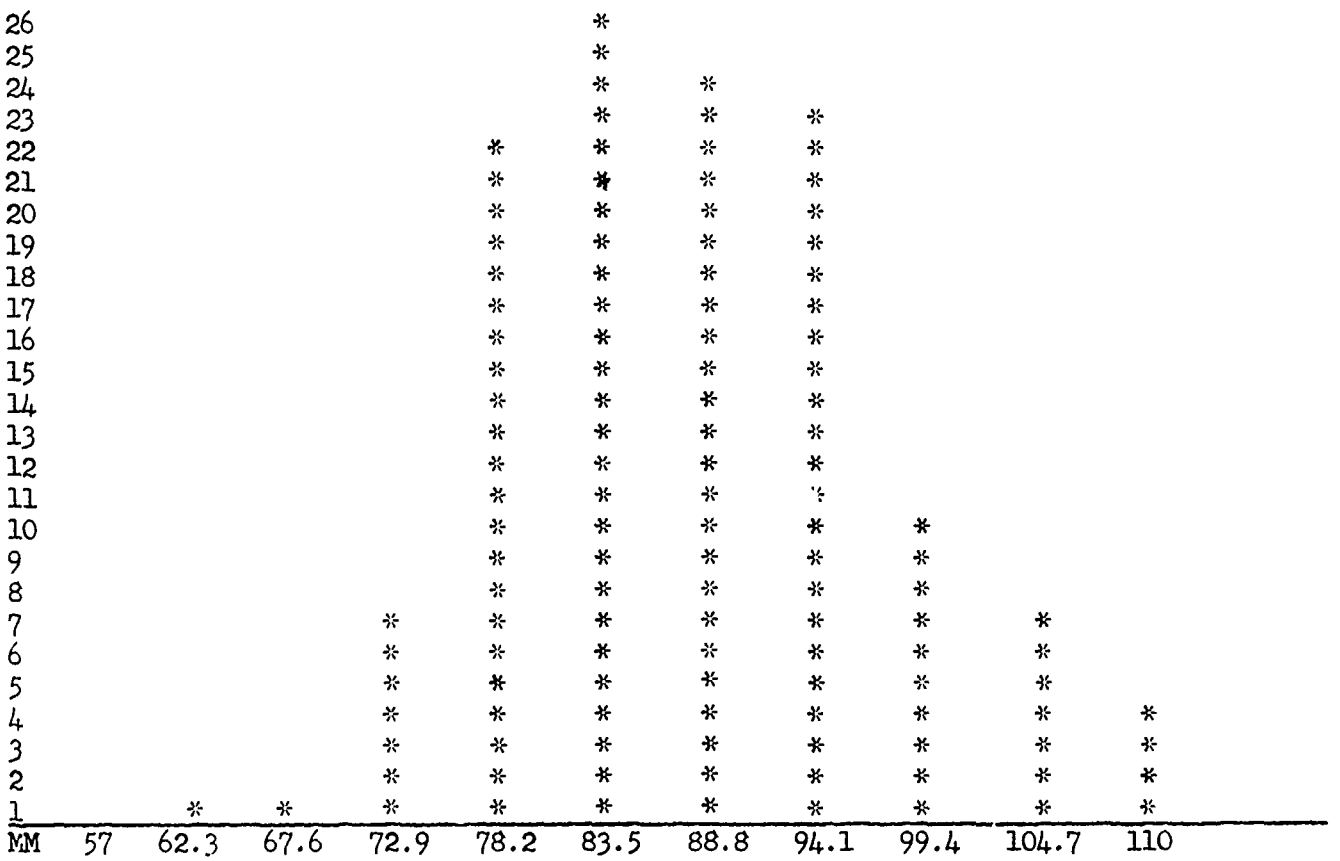


TABLE XVI

Frequency Distribution of Size Medium Biaural Breadth

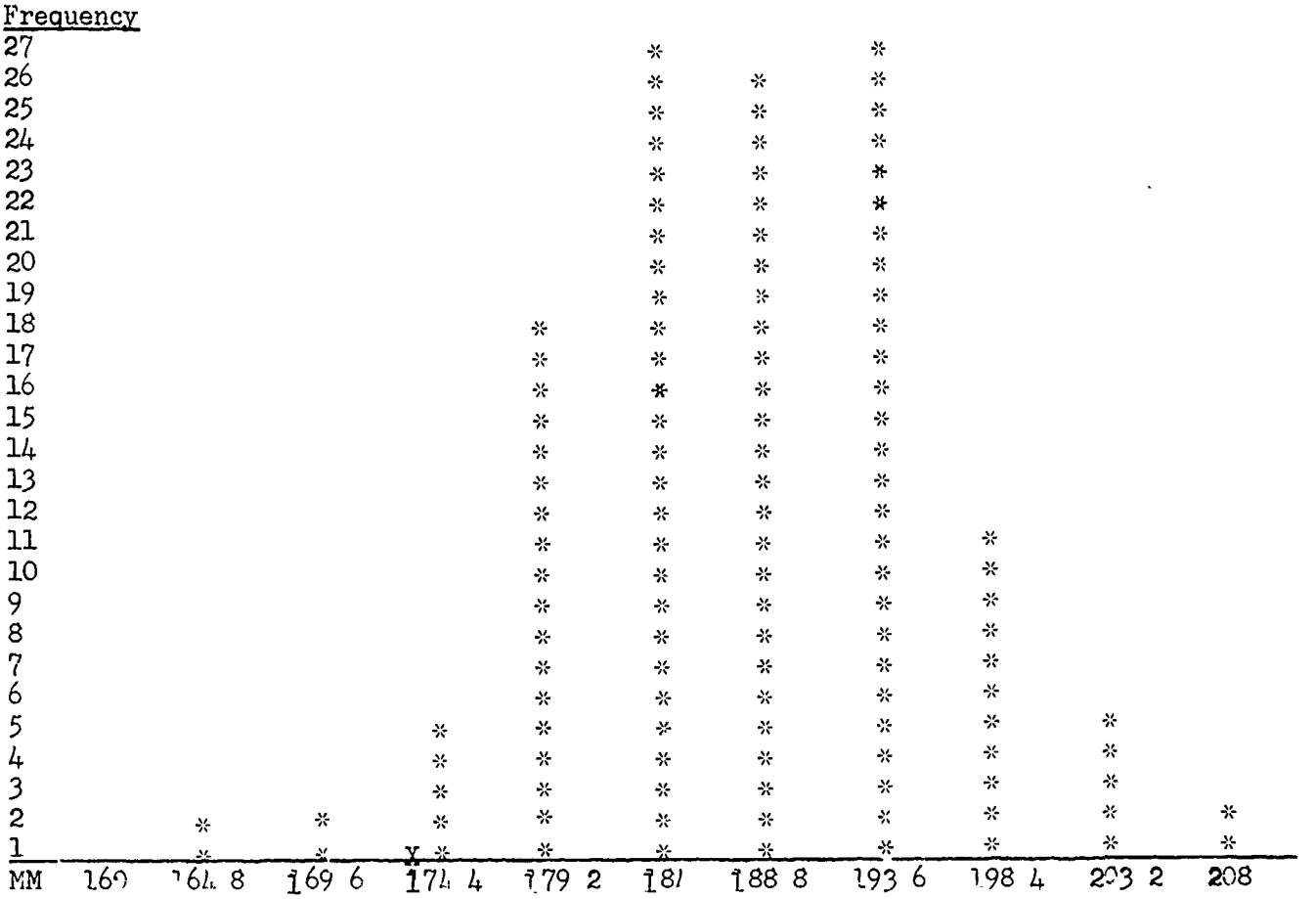


TABLE XVII

Frequency Distribution of Size Medium Menton to Vertex

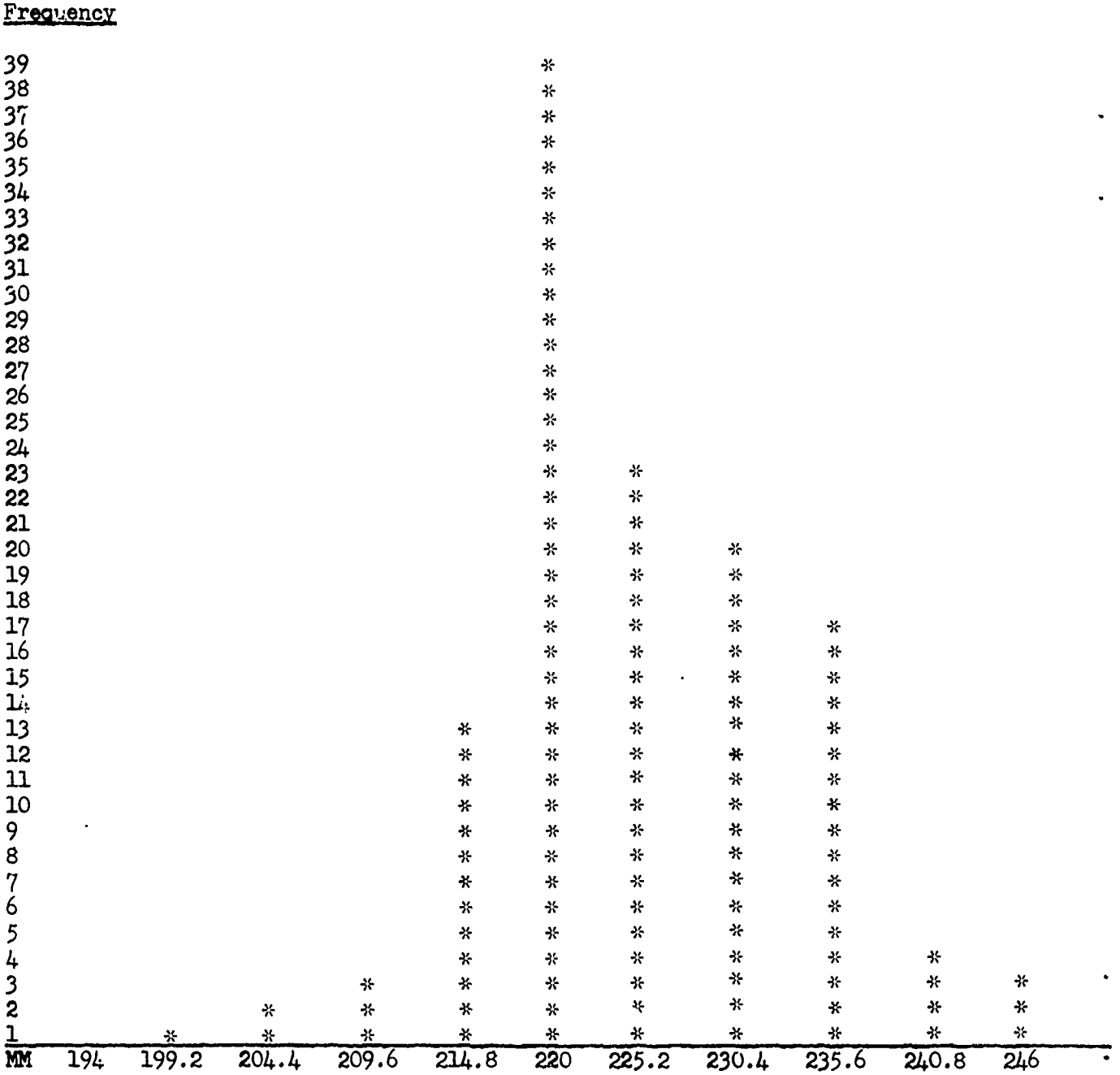


TABLE XVIII

Analysis of Head Dimension of a Military Population Sized Large Population - 123

Dimension	Mean(MM)	STD DEV	Minimum(MM)	Maximum(MM)
Circumference	584.28	8.96	547.00	619.00
Length	199.00	6.01	187.00	215.00
Breadth	156.41	5.71	144.00	170.00
Height	131.33	5.86	117.00	145.00
Glabella-Vertex	86.37	9.14	69.00	113.00
Ear to Ear	190.89	8.90	160.00	200.00
Menton Vertex	225.43	10.27	205.00	254.00

TABLE XIX

Frequency Distribution of Size Large Head Circumference

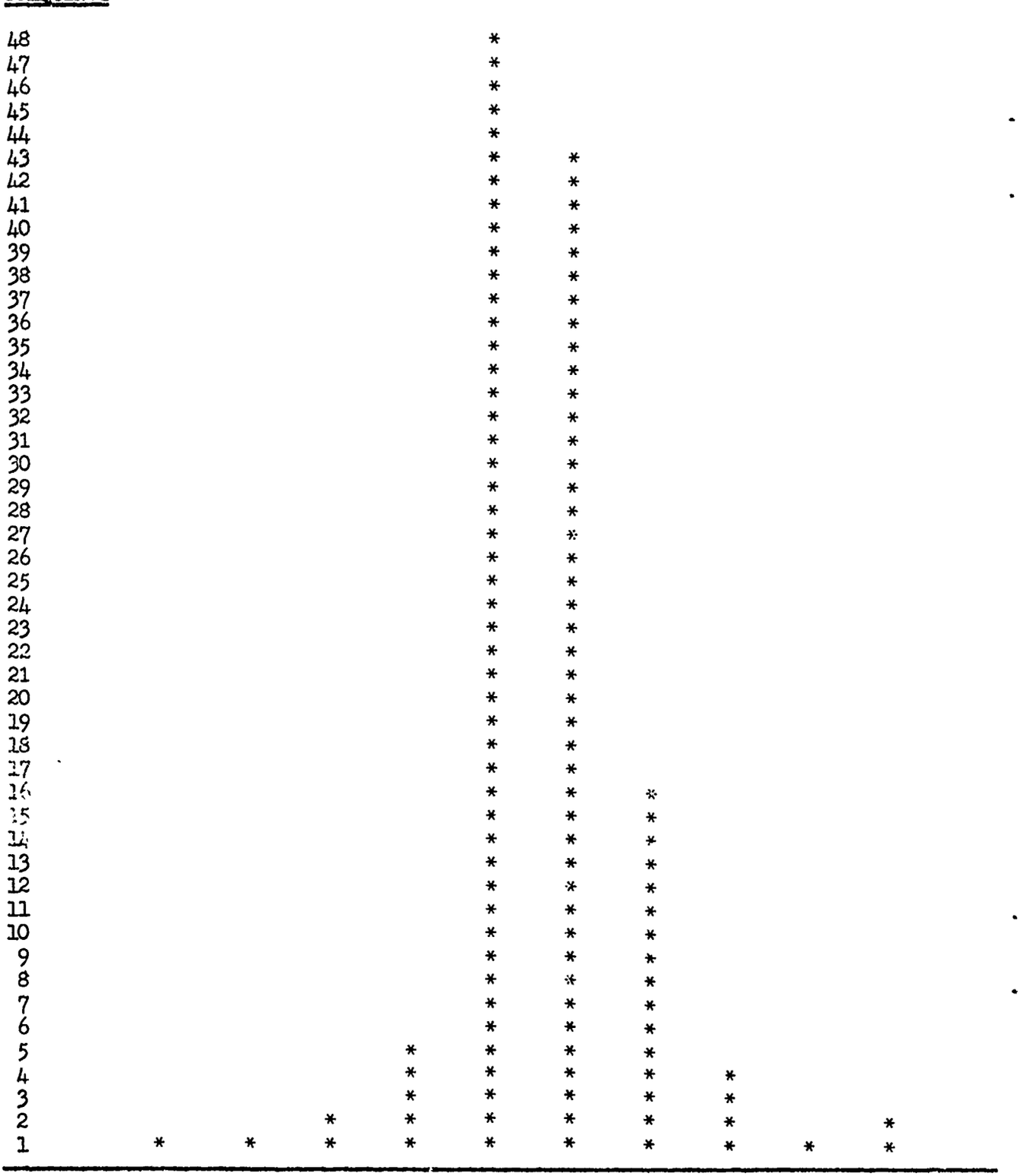


TABLE XX

Frequency Distribution of Size Large Head Length

Frequency											
29							*				
28							*				
27							*				
26							*				
25							*				
24							*				
23							*				
22					*		*				
21					*		*				
20					*		*				
19					*		*				
18					*		*				
17					*		*				
16					*		*				
15					*	*	*				
14					*	*	*				
13					*	*	*	*			
12					*	*	*	*			
11				*	*	*	*	*			
10			*	*	*	*	*	*	*		
9			*	*	*	*	*	*	*		
8			*	*	*	*	*	*	*		
7			*	*	*	*	*	*	*		
6		*	*	*	*	*	*	*	*		
5		*	*	*	*	*	*	*	*	*	
4		*	*	*	*	*	*	*	*	*	
3		*	*	*	*	*	*	*	*	*	
2		*	*	*	*	*	*	*	*	*	*
1		*	*	*	*	*	*	*	*	*	*
MM	187	189.8	192.6	195.4	198.2	201	203.8	206.6	209.4	212.2	215

TABLE XXI

Frequency Distribution of Size Large Head Breadth

Frequency											
20						*		*			
19					*	*		*			
18					*	*	*	*			
17					*	*	*	*			
16				*	*	*	*	*			
15				*	*	*	*	*			
14				*	*	*	*	*			
13				*	*	*	*	*			
12				*	*	*	*	*			
11				*	*	*	*	*			
10				*	*	*	*	*			
9				*	*	*	*	*	*		
8				*	*	*	*	*	*	*	
7				*	*	*	*	*	*	*	
6			*	*	*	*	*	*	*	*	
5		*	*	*	*	*	*	*	*	*	
4		*	*	*	*	*	*	*	*	*	
3		*	*	*	*	*	*	*	*	*	*
2		*	*	*	*	*	*	*	*	*	*
1		*	*	*	*	*	*	*	*	*	*
MM	144	146.6	149.2	151.8	154.4	157	159.6	162.22	164.8	167.4	170

TABLE XXII

Frequency Distribution of Size Large Head Height

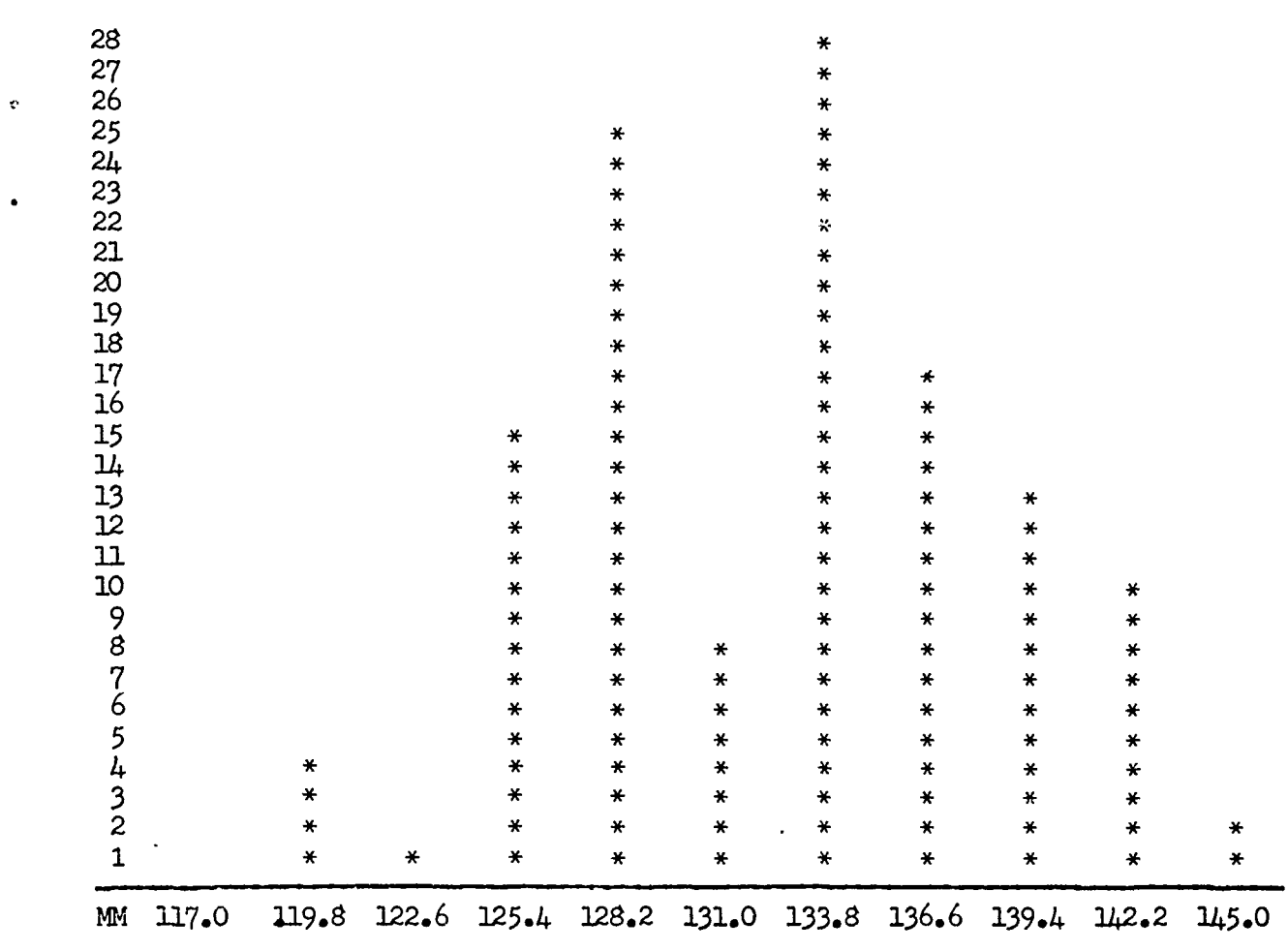


TABLE XXIII

Frequency Distribution of Size Large Glabella to Vertex

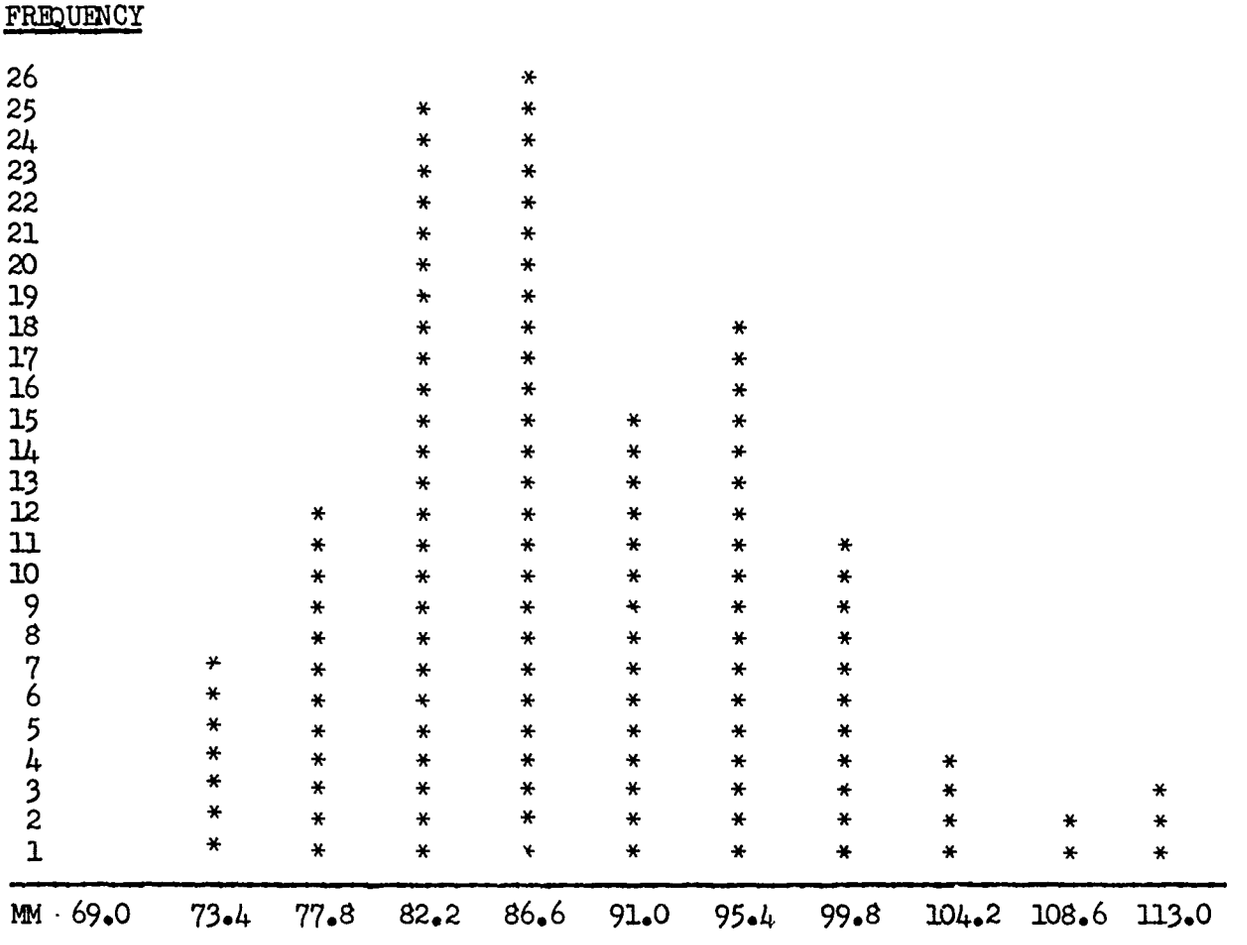


TABLE XXIV

Frequency Distribution of Size Large Biaural Breadth

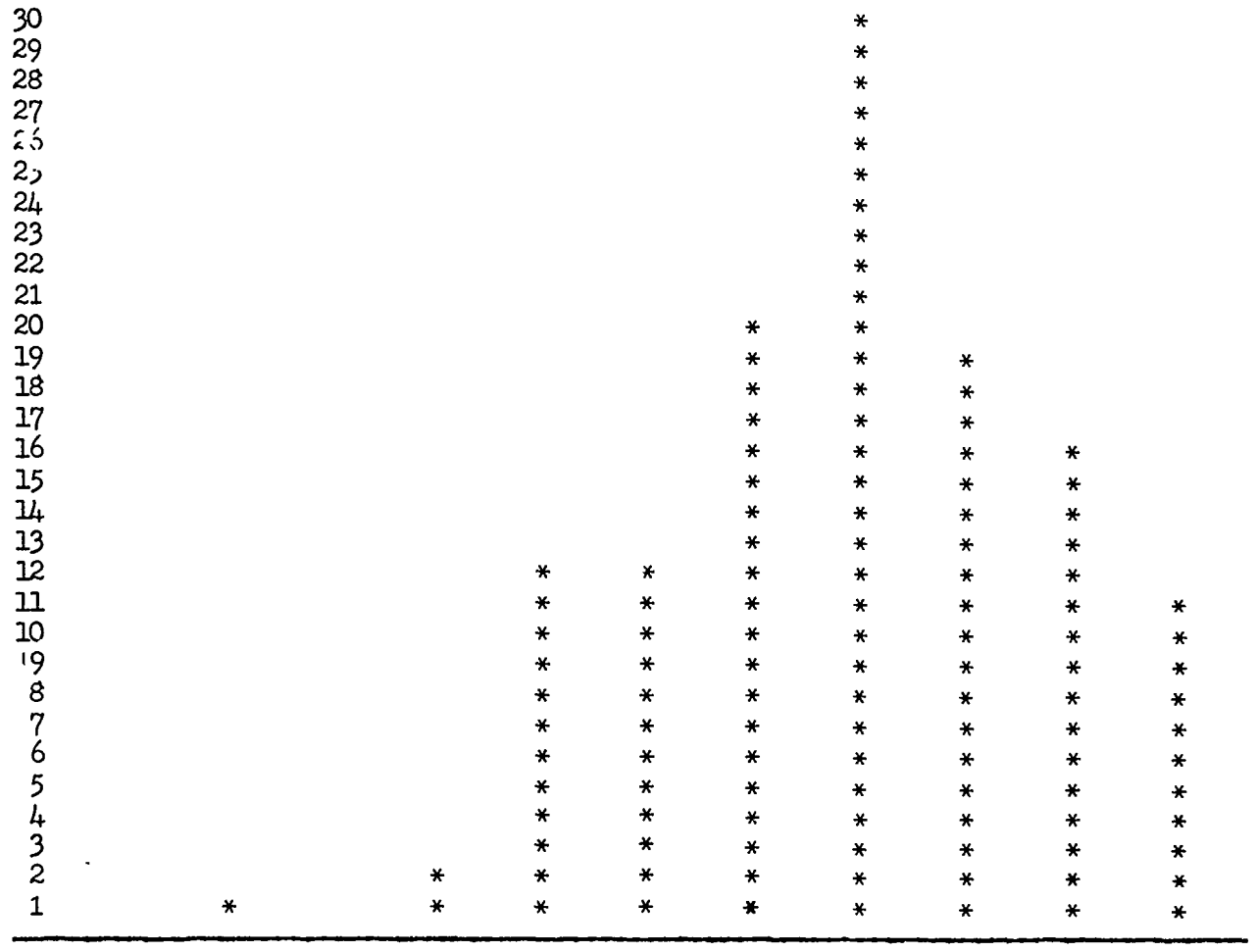
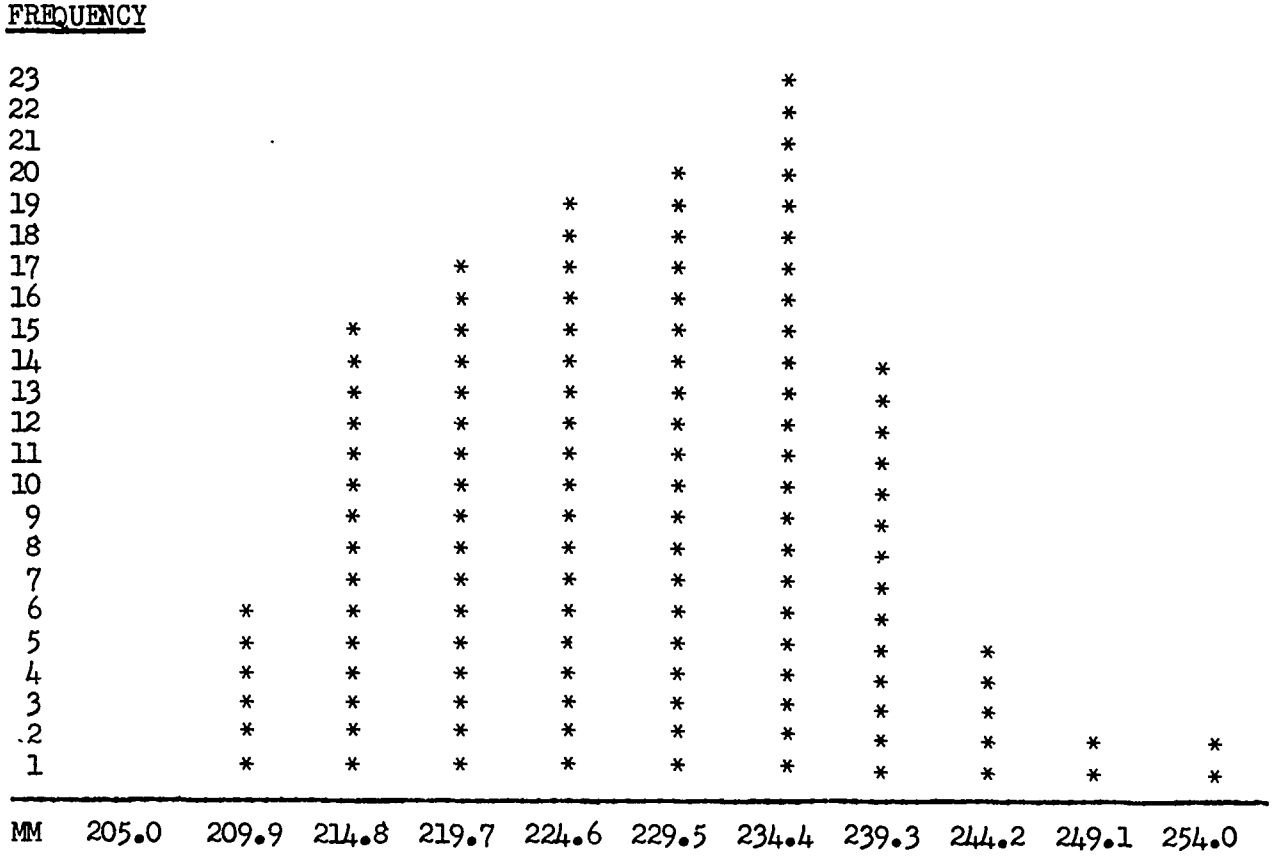


TABLE XXV

Frequency Distribution of Size Large Menton to Vertex



PROBE STATISTICS

Percent of Probe Reading = > 12.7mm - 95

Percent of Probe Readings = < 12.7mm - 5

Percent of Subjects having Sufficient Stand-off on all Probes - 65

Percent of Subjects with one or more probe readings < 12.7mm - 35

TABLE XXVI
STAND-OFF DATA

Number of Probe Readings < 12.7mm

Probe Stations		Small (82 subjects)		Medium (198 subjects)		Large (223 subjects)	
	Head Dimension Significance		Avg. Probe Reading (mm)		Avg. Probe Reading (mm)		Avg. Probe Reading (mm)
1	Height	17	9.1	7	9.7	19	9.1
2	Crown	0	—	0	—	0	—
3	"	2	10.2	0	—	0	—
4	"	1	8.1	0	—	0	—
5	"	1	7.6	0	—	1	11.2
6	"	0	—	0	—	0	—
7	"	0	—	0	—	0	—
8	Length	0	—	8	10.7	3	10.2
9	Width	19	10.2	24	9.9	7	10.9
10	Length	1	11.2	8	10.9	15	9.9
11	Length	4	10.2	4	10.9	21	9.7
12	Width	25	9.7	50	9.1	3	9.7
13	Length	1	11.2	15	10.2	8	9.9